

## COMMENTARY

## Possible neural oscillatory mechanisms underlying learning

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## ABSTRACT

In response to Voelker et al. (this issue), we argue for a wide array of neural oscillatory mechanisms underlying learning and practice. While the authors propose frontal theta power as the basis for learning-induced neuroplasticity, we believe that the temporal dynamics of other frequency bands, together with their synchronization properties can offer a fuller account of the neurophysiological changes occurring in the brain during cognitive tasks.

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Voelker et al. (this issue) offer a fascinating view on the molecular basis of learning, a line of study that clearly merits investigation.

While we agree with the premise that changes in white matter can underlie behavioral manifestations of learning, we believe that learning and practice might be based on a much wider array of different neural mechanisms.

We would like to mention a possible extension of the working hypothesis that considers the frontal theta rhythm as the basis for neuroplasticity mechanisms coupled with learning, as the authors suggest.

We believe that apart from local oscillatory mechanisms, such as frontal theta power, global mechanisms, such as long-range coherence, should be taken into account. For example, information about functional cooperation between cortical regions during learning can be obtained by analyzing the synchronization properties of the electroencephalogram (EEG) signal within certain frequency bands.

In the language-learning domain, for instance, increased long-range gamma band phase coherence has been shown to accompany successful rule learning (De Diego-Balaguer, Fuentemilla, & Rodriguez-Fornells, 2011). These results are in line with the view that an increase in coherence in the gamma band 'could fulfil the criteria required for the formation of Hebbian cell assemblies, binding together parts of the brain that must communicate with one another in order for associative learning to take place' (Miltner, Braun, Arnold, Witte, & Taub, 1999, p. 434).

Also, our data (Kepinska, Pereda, Caspers, & Schiller, *in prep.*) provide evidence for the role of gamma band coherence in the process of learning. Employing a bivariate, frequency-specific index of phase synchronization termed Phase Locking Value (PLV, Mormann, Lehnertz, David, & Elger, 2000), we evaluated the contribution of four frequency bands (alpha, beta, gamma, and theta) to online learning of novel grammar. We observed a negative correlation between global PLV values of the slow frequency bands (theta and alpha) and scores on the learning task, and a positive correlation between the high frequency bands (gamma and beta) and the scores. However, only the gamma band global PLV values proved predictive of the performance according to a stepwise linear regression analysis.

In the context of investigations into neuroplasticity mechanisms, it therefore seems vital to us not to limit the observations of the EEG signal to theta band power, but to expand the approach and include the temporal dynamics of other frequency bands, together with their synchronization properties as well. Such an approach can offer a fuller account of the neurophysiological changes occurring in the brain during cognitive tasks.

## Disclosure statement

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